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SYMPOSIUM ON ECOLOGY AND THE LAW: SOME PRINCIPLES OF CONSERVATION BIOLOGY, AS THEY APPLY TO ENVIRONMENTAL LAW

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LEXISNEXIS SUMMARY:
... Conservation is not as simple today as in the past. ... Several scientists have pointed out that Type II errors are more dangerous than Type I errors in applied sciences such as medicine, environmental engineering, and conservation biology because they can result in irreversible damage, for 8131*897 example death of a patient due to side effects of a drug, death and sickness of many innocent people in the cases of Bhopal and Chernobyl, or extinction of species. ... Although ecosystem management is the buzzword of the day, management of individual species on a population or metapopulation level remains a necessary part of any conservation strategy. Without individual attention, many species that have declined due to human activity are likely to become extinct in the near future. ... Keeping species well distributed is therefore a sensible conservation goal and corresponds to the well-accepted "multiplicity" principle, where it is preferable to have many reserves rather than few. ... In metapopulation theory, an unoccupied patch of suitable habitat isolated by fragmenta- 8131*902 tion is less likely to be colonized or recolonized by the target species. ... The most appropriate target species for conservation are generally those most sensitive to human disturbance. ...

TEXT:
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Introduction

Conservation is not as simple today as in the past. One hundred years ago it seemed that if we could just stop the plume hunters from shooting egrets to decorate ladies' hats, and if we could only save a few areas of spectacular scenery in national parks, we were doing well. Somewhat later it became apparent that we had to protect many kinds of habitats - wetlands, grasslands, deserts, forests of all kinds - to save wildlife. To that end, we established a series of reserves including national wildlife refuges, research natural areas, state nature preserves, and private sanctuaries managed by groups such as The Nature Conservancy and National Audubon Society. The tacit assumption was that these little enclaves of nature would persist forever in the stable "climax" condition in which we found them.

As ecology, genetics, and other biological sciences matured, they slowly began to have more influence on conservation philosophy, and in the last two decades they have begun to inform conservation practice. But as the influence of scientists on environmental policy increased, so did doubts about our ability to comprehend nature.

Ecological science has undergone significant changes in recent years. Among the new paradigms in ecology, none is more revolutionary than the idea that nature is not delicately balanced in equilibrium, but rather is dynamic, often unpredictable, and perhaps even chaotic. n1 It follows that classical preservationist approaches to conservation, to the extent that they attempt to hold nature static, do not reflect realities of nature. A related idea is that ecological phenomena operate across vast landscapes, and that parks and other areas set aside for their natural qualities are inevitably buffeted by exotic spe- 8131*894 cies invasions, uncontrolled human activities, disruptions of hydrology, and other cross-boundary effects.

Nature cannot be expected to manage itself and maintain all of its components in a world where natural processes have been dramatically altered. Even the largest wild areas on earth are changing inexorably due to natural forces and are now being affected by long-distance transport of pollutants, thinning of the ozone layer, and probably global warming. As undeveloped areas become smaller and more isolated from one another, they are affected more strongly by their surroundings and are less likely to maintain their biodiversity. Thus, the new ecological paradigm, described in Professor Meyer's article, suggests that reserves are not enough. n2 If we are really interested in maintaining ecological processes and the services they provide to human society, then conservation must be extended to entire landscapes or regional ecosystems. Almost all conservationists agree that some sort of "ecosystem management" is necessary to maintain biodiversity and ecological integrity in today's world. n3 In this Article, I offer some principles and concepts from conservation biology that might help us manage ecosystems in a prudent and responsible fashion. These principles also have implications for environmental law. But first I will examine briefly the issue of values.

I. Conservation Biology and Values

The emergence of conservation biology as a distinct discipline in the late 1970s and its flowering in the mid-80s with the founding of the Society for Conservation Biology can be traced to the increasing interest of ecologists, geneticists, and other "basic" biological scientists in conservation problems and the dissatisfaction of these scientists with wildlife management, forestry, fisheries, and other traditional natural resource disciplines. The resource disciplines were concerned with mostly utilitarian ends and focused on a narrow range of the biological spectrum, chiefly game birds and mammals, edible fish, commercial trees, and livestock forage. Although the resource disciplines had already begun to broaden in the 1970s with more attention to "nongame" and endangered species, the broadening was not great or fast enough for conservationists interested in biodiversity, the total variety of life on earth. Moreover, it was quickly recognized that because 8131*895 conservation problems are inherently transdisciplinary, conservation biology must involve not only biologists, but also geographers, sociologists, economists, philosophers, lawyers, political scientists, educators, artists, and other professionals.

A distinguishing feature of conservation biology is that it is mission oriented. n4 Underlying any mission is a set of values. Philosophers of science now recognize that no science is value free, despite all we were taught in school about the strict objectivity of the scientific method. Conservation biology is more value-laden than most sciences because it is not concerned with knowledge for its own sake but rather is directed toward particular goals. Maintaining biodiversity is an unquestioned goal of conservation biologists. Sometimes an exercise in conservation biology is highly specific in its mission. For example, we might be interested in maintaining a viable population of Furbish's lousewort, defined perhaps as having a 99% chance of surviving for 500 years. Alternately, we might propose goals that are broad and ambitious. For instance, the goals of The Wildlands Project, an effort in which I and many other conservation biologists and activists are involved, are to (1) represent all types of ecosystems across their natural range of variation in protected areas; (2) maintain viable populations of all native species in each region, with most attention to species especially sensitive to human activities; (3) sustain the full suite of ecological and evolutionary processes; and (4) create a conservation system that is adaptable to a changing environment. n5

Underlying the goals and objectives of conservation biology, whether general or specific, is the fundamental value assumption that biodiversity is good and ought to be preserved. I emphasize this point because many detractors of conservation do not seem to share this assumption. Getting to the heart of an environmental conflict often requires that we examine differences among people in their basic value systems. As an example, the idea that biodiversity is good and that species have inherent value is implicit in the U.S. Endangered Species Act ("ESA") and to some extent in the National Forest Management Act and other pieces of environmental legislation. n6 People 8131*896 who seek to weaken these laws question the intrinsic value of species and attempt to put the burden of proof on environmentalists to demonstrate that a species provides direct benefits to human society and therefore warrants protection.

In practice, if not in intent, the burden of proof in the ESA and National Environmental Policy Act ("NEPA") is already on those who wish to protect the species or the environment. In NEPA decisions, a dam, highway, or other project is considered benign unless an environmental impact statement convincingly demonstrates otherwise. n7 In listing decisions under the ESA, the burden is on the citizens who petition to list a species to present data on threat to the species that the Fish and Wildlife Service considers "substantial." n8

Putting the burden of proof on those who would protect the environment is consistent with conventional practice in scientific research, where the statistical significance of a result corresponds to how low the chance is of committing a Type I error. A Type I error occurs when one rejects a true null hypothesis and claims an effect (say, of a real estate development or a timber sale) when none really exists. Conventional statistical analyses are designed to minimize the probability of Type I errors, but in so doing they increase the chance of committing a Type II error, failing to reject a false null hypothesis or claiming no effect when one actually exists. The scientific preference for committing Type II rather than Type I errors is congruent with the "innocent until proven guilty" standard in criminal law, as opposed to cases in torts. n9 In criminal law, it is assumed that acquitting a guilty person is not as bad as convicting an innocent person. However, the innocent until proven guilty standard sometimes imposes unacceptable risks on society. Several scientists have pointed out that Type II errors are more dangerous than Type I errors in applied sciences such as medicine, environmental engineering, and conservation biology because they can result in irreversible damage, n10 for 8131*897 example death of a patient due to side effects of a drug, n11 death and sickness of many innocent people in the cases of Bhopal and Chernobyl, n12 or extinction of species. n13 As exemplified by Taylor and Gerrodette:

Consider a medical test that determines whether a patient has some deadly disease. Physicians are properly less concerned with a false positive (concluding that the patient has the disease when she does not) than with a false negative (concluding that the patient does not have the disease when she does). Conservation biologists deal with the health of species and ecosystems and should be similarly concerned with false negatives. n14

The philosophy underlying conservation biology and other applied sciences is one of prudence: in the face of uncertainty, applied scientists have an ethical obligation to risk erring on the side of preservation. Thus, anyone attempting to modify a natural environment and put biodiversity at risk is guilty until proven innocent. This shift in burden of proof is consistent with the precautionary principle, which is gaining increased support in many professions. A precedent for this shift can be found in the U.S. Food and Drug Administration's requirement that the drug industry prove that a drug is not harmful before it is licensed. Belsky recognized that shifting the burden of proof is a major challenge for environmental law. n15 Legal scholars have their work cut out for them here: when the burden of proof is shifted from conservationists to developers, this poses serious questions about the enjoyment of private property rights, "taking" of property, and just compensation.

II. Principles of Conservation Biology

In the remainder of this Article I will review what I recognize as some emerging principles of conservation biology. Like ecology, conservation biology has so far been largely a science of case studies. Whatever generalities exist, like "everything is connected to everything else," seem trite. But despite the anecdotal nature of much of our knowledge in conservation biology, some principles or empirical 8131*898 generalizations are becoming clear. These principles will hopefully be useful to policy makers, legal scholars, land-use planners, land managers, and conservationists in general, and they can be adapted to scales ranging from local land-use plans to global strategies. I begin with some general principles and then move to specific tasks such as reserve design and ecosystem management. Although any principle is a generalization and will have exceptions, taken together these principles provide a robust basis for conservation planning.

A. General Principles

The general principles of conservation biology emerge from an appreciation of the complexity of nature, and an understanding that we will never know precisely how nature works. Thus, we had better be as cautious and gentle as possible in our manipulations.

"Ecosystems are not only more complex than we think, but more complex than we can think." n16 This quote from ecologist Frank Egler was probably based on a 1927 statement by evolutionary biologist J.B.S. Haldane, who said "my suspicion is that the universe is not only queerer than we suppose, but queerer than we can suppose." n17 In any case, the proper response to this situation is humility. Humility demands that we prefer erring on the side of preservation to erring on the side of development. Thus, humility demands a shift in burden of proof as discussed earlier.

The less data or more uncertainty involved, the more conservative a conservation plan must be. Some non-trivial level of uncertainty accompanies all planning decisions. When information on species locations, population sizes and trends, interspecific interactions, responses to disturbance, and other factors is scarce or questionable, the best interim strategy is one that minimizes development and other human disturbance during the time needed to gather the necessary biological information. For example, when we discovered that not nearly enough data were available for construction of a long-term conservation plan, the Scientific Review Panel for the coastal sage scrub in southern California called for an interim plan involving not more than five percent loss of habitat in each planning subregion during a period of three to six years over which field inventories and research will be conducted. Furthermore, if the plan is implemented as intended, 8131*899 habitat losses will be restricted to patches of low to moderate conservation value such as small sites lacking rare species and surrounded by development.

Natural is not an absolute, but a relative concept. Because human impacts penetrate all boundaries, no purely natural areas exist anywhere in the world today. Yet few would disagree that a remnant of virgin forest or tallgrass prairie is more natural than a clearcut or a shopping mall.

Conservation biology is highly value-laden. No science is value-free, but values and ethics play a more prominent role in applied, mission-oriented sciences like conservation biology than in basic research. The greatest objectivity follows from stating biases, values, interests, predilections, and goals straightforwardly. Such openness may not seem appropriate in a courtroom, where the assumption seems to be that science is only concerned with facts, but is entirely consistent with the oath of honesty.

Conservation must be goal-directed. Explicit (though not necessarily quantitative) goals are better than vague goals, and ambitious goals are usually preferable to weak goals. Without stated goals, conservation programs flounder. In an apparent effort to appear reasonable, some conservationists begin their bargaining with goals that are already highly compromised. Because few goals are ever fully attained, starting with a compromise may mean ending up with nothing.

In order to be comprehensive, biodiversity conservation must be concerned with multiple levels of biological organization and many different spatial and temporal scales. There is no one best scale or level of organization for conservation research or action. The trick is finding the best scale for solving each specific problem, then integrating across scales for the overall conservation strategy.

Conservation biology is interdisciplinary, but biology must determine the bottom line. Human cultural systems are far more adaptable than biological systems. Thus, although sociological and economic concerns must enter into any conservation planning exercise, the vital needs of nonhuman species must not be compromised. Furthermore, because a healthy economy ultimately depends on a healthy ecosystem, human actions that are not compatible with the integrity of the ecosystem should not be permitted. 8131*900

B. Principles of Reserve Design and Management for Target Species

Although ecosystem management is the buzzword of the day, management of individual species on a population or metapopulation level remains a necessary part of any conservation strategy. Without individual attention, many species that have declined due to human activity are likely to become extinct in the near future. Besides, we know much more about managing species than managing ecosystems. The Interagency Scientific Committee that developed a conservation strategy for the northern spotted owl offered five general principles for reserve design that they characterized as "widely accepted" within the community of conservation biologists. n18 Few scientists have disagreed with their bold statement. I paraphrase these five reserve design principles below, then add several of my own that apply to species especially sensitive to human activity.

Species well distributed across their native range are less susceptible to extinction than species confined to small portions of their range. n19 The idea here is that a widely distributed species will be unlikely to experience a catastrophe, disturbance, or other negative influence across its entire range at once. For instance, a severe drought may dry up the breeding ponds used by a species of salamander for several years in a row across two or three states. If that salamander occurs nowhere else, it may become extinct. However, if the salamander is distributed broadly, at least some areas within its range are likely to contain breeding ponds that do not dry out completely. From those refugia, the species can slowly recolonize areas where it had been eliminated. As an extreme example, a plant species confined to the slope of a single volcano might be wiped out by one eruption. Keeping species well distributed is therefore a sensible conservation goal and corresponds to the well-accepted "multiplicity" principle, where it is preferable to have many reserves rather than few. n20 The provision of the Endangered Species Act that allows for listing of local populations, even when the species as a whole is not threatened, is consistent with this principle. n21 8131*901

Large blocks of habitat, containing large populations of a target species, are superior to small blocks of habitat containing small populations. n22 The principle of "bigness" is another of the universally accepted generalizations of conservation biology. n23 All else being equal, large populations are less vulnerable than small populations to extinction. A larger block of suitable habitat will usually contain a larger population. In line with the preceding principle, large blocks of habitat are also less likely to experience a disturbance throughout their area. Thus, refugia and recolonization sources are more likely to occur in large blocks of habitat than in small blocks, thus enhancing population persistence. n24

Blocks of habitat close together are better than blocks far apart. n25 Many organisms are capable of crossing narrow swaths of unsuitable habitat, such as a trail, a narrow road, or a vacant lot; far fewer are able to successfully traverse a six-lane highway or the City of Chicago. In the absence of impenetrable barriers, habitat blocks that are close together will experience more interchange of individuals of a target species than will blocks far apart. If enough interchange occurs between habitat blocks, they are functionally united into a larger population that is less vulnerable to extinction for any number of reasons. n26

Habitat in continuous blocks is better than fragmented habitat. n27 This rule follows logically from the previous two but also brings in some new considerations. Fragmentation involves a reduction in size and an increase in isolation of habitats. The theory of island biogeography predicts that either of these processes will lead to lower species richness due to decreased immigration rates (in the case of isolation) and increased extinction rates (in the case of small size). n28 Thus, a small island far from the mainland is predicted to have the lowest species richness. Looking at a single target species, as is now the fashion in fragmentation studies, a small and isolated habitat patch is expected to have a smaller population and less opportunity for demographic or genetic "rescue" from surrounding populations. n29 In metapopulation theory, an unoccupied patch of suitable habitat isolated by fragmenta- 8131*902 tion is less likely to be colonized or recolonized by the target species. n30 If enough connections between suitable habitat patches are severed, the metapopulation as a whole is destablized and less likely to persist.

But fragmentation involves more than population effects for single species. Effects at community, ecosystem, n31 and landscape levels are also well documented. n32 Briefly, problems at these higher levels include abiotic and biotic edge effects that reduce the area of secure interior habitat in small habitat patches and often lead to proliferation of weedy species; increased human trespass and disturbance of sensitive habitats and species; and disruption of natural disturbance regimes, hydrology, and other natural processes. The end result of fragmentation is often a landscape that has lost sensitive native species and is dominated by exotics and other weeds. Although species richness at the local or landscape scale is often higher after fragmentation than in the undeveloped condition, this richness is misleading because it is accompanied by a homogenization of floras and faunas at a broader scale and by a net loss of sensitive species; the global consequence is biotic impoverishment.

Interconnected blocks of habitat are better than isolated blocks. Connectivity - the opposite of fragmentation - has become one of the best accepted principles of conservation planning. Despite continuing arguments over benefits versus costs of particular corridor designs, n33 few conservation biologists would disagree that habitats functionally connected by natural movements of organisms are less subject to extinctions than habitats artificially isolated by human activity. It is also 8131*903 probable that corridors or linkages will function better when habitat within them resembles that preferred by target species. For example, although we do not know exactly what types of habitats the species associated with old-growth forests will travel through, old forests are likely to provide better linkages than fresh clearcuts.

Blocks of habitat that are roadless or otherwise inaccessible to humans are better than roaded and accessible habitat blocks. Roads and other providers of human access often lead to high mortality rates for large carnivores, furbearers, desert tortoises, commercially valuable plants such as cacti, and other species exploited or persecuted by people. Although the ultimate solution to these problems must involve education and change in human values and behavior, the immediate need is to restrict access to habitats of sensitive species. For example, land managing agencies often have policies (which may or may not be enforced) calling for road densities not exceeding 0.5 miles per square mile in wolf or grizzly bear habitat. Roads also cause other problems. Roadkill is a primary source of mortality for many species in regions with heavy traffic; dirt roads contribute sediments to streams; and roads are barriers to movement of some small vertebrates and invertebrates. For these and other reasons, n34 roadless areas should be protected, roads should be closed whenever possible, and busy roads should be equipped with underpasses or other wildlife movement passages.

"Conservation strategy should not treat all species as equal but must focus on species and habitats threatened by human activities." n35 This statement from Jared Diamond seems logical enough, but it is amazing how much time and money has been spent studying and managing species that do not really require human assistance (e.g., white-tailed deer). Similarly, high species diversity in clearcuts and other human-disturbed habitats has been used to justify intensive forestry and other forms of manipulative management, even though the species that thrive in such habitats are mostly opportunistic weeds. The most appropriate target species for conservation are generally those most sensitive to human disturbance.

Populations that fluctuate widely are more likely to go extinct than populations that are more stable over time. Mean population size is sometimes a poor indicator of vulnerability. A population with a rela- 8131*904 tively large mean size but high variance may be more likely to go extinct than a smaller but more stable population. n36 Large-bodied animal species, although more vulnerable to many specific threats, generally fluctuate less and therefore can probably be viable with smaller populations.

Disjunct or peripheral populations of species are more likely to be genetically impoverished but also genetically distinct than are central populations. This well-documented pattern is a direct consequence of reduced gene flow to isolated or marginal populations. The pattern presents a dilemma because populations with lower heterozygosity are likely to be less adaptable to future environmental change n37 and therefore might be seen as less important to conserve. Marginal populations are also likely to be in suboptimal habitat. Thus, conservation at the species level may be more effective when directed to the central portion of each species' range. On the other hand, disjunct or peripheral populations are likely to have diverged genetically from central populations due to genetic drift, adaptation to local environments, or both. Directional selective pressures can be expected to be intense for these populations. If we are concerned with maintaining opportunities for speciation - future biodiversity - then conservation of peripheral and disjunct populations is critical. Again, the provision of the Endangered Species Act that allows for listing of distinct populations, even when the species as a whole is not threatened, makes biological sense. Conservation of species across their native ranges is the optimal strategy.

C. Ecosystem Management

The idea that we can manage ecosystems is arrogant and misleading. However, management based on some understanding of ecosystems and aimed at protecting whole communities or habitat mosaics is certainly sensible. Most of the principles stated above for target species also apply to ecosystem management, because maintaining the integrity of an ecosystem requires that the most sensitive species within that ecosystem remain viable. However, management at the ecosystem level requires some rules of its own.

Maintaining viable ecosystems is usually more efficient, economical, and effective than a species-by-species approach. Although, as 8131*905 noted earlier, many sensitive species require individual attention in order to avoid extinction, focusing on every species individually is impossible. There are likely to be thousands of species inhabiting any given region, if we include microbes, soil invertebrates, and other poorly known groups. The "coarse filter" approach n38 of representing all types of habitats and communities in areas managed for their natural values is probably the most inclusive of all conservation strategies. The goal of the Gap Analysis project of the National Biological Survey is to evaluate how well native vegetation types and associated species are represented in protected areas. n39

Biodiversity is not distributed randomly or uniformly across the landscape. In establishing protection priorities, focus on "hot spots." Hot spots are areas of concentrated conservation value, such as centers of endemism or areas of high species richness. Hot spots can be recognized at many spatial scales. For example, globally, the humid tropics stand out as hot spots of species richness, with the greatest diversity for most taxa in Central and South America. n40 But within an area such as the Amazon Basin, biologists have identified hot spots of endemism. Some kinds of organisms, such as coniferous trees, are most diverse in North America. Looking more closely, the greatest diversity of conifers appears to be the seventeen species in the Russian Peak area of northern California. n41 Every landscape has areas of concentrated biodiversity. Map overlays that display multiple conservation criteria can show the locations of these hot spots.

Ecosystem boundaries should be determined by reference to ecology, not politics. Ecosystems do not respect property and jurisdictional lines. Ecologists often say that the boundaries of all ecosystems - even the biosphere - are open, exchanging energy and materials with other systems. But of course boundaries are not entirely arbitrary. Topography, geology, soils, and other factors often create discontinuities on the landscape. Ecosystems can be delimited by vegetation, watersheds, or physiography, all of which are hierarchically organized but mappable. Boundaries defined on the basis of ecological criteria are more useful for conservation planning than 8131*906 those defined by conventional political or administrative jurisdiction. The scale and boundaries of the ecosystem should correspond to the management problems at hand. A comprehensive conservation strategy must consider multiple scales.

Because conservation value varies across a regional landscape, zoning is a useful approach to land-use planning and reserve network design. Some advocates of ecosystem management favor a "landscape without lines" approach, where human activities are spread throughout a landscape. This approach is not likely to offer sufficient protection to hot spots and areas especially sensitive to human disturbances. A concentric zoning model with protection increasing inward and intensity of human use increasing outward is recommended. n42

Ecosystem health and integrity depend on the maintenance of ecological processes. Flow of energy and cycling of nutrients are fundamental processes of all ecosystems. Photosynthesis, herbivory, predation, disease, decomposition, competition, cooperation, disturbance, succession, erosion, deposition, and other biotic and abiotic processes assure that energy keeps flowing and nutrients keep cycling. Disruption of the characteristic processes of any ecosystem will likely lead to biotic impoverishment. Although even grossly impoverished ecosystems (for instance, an abandoned strip mine or sewage lagoon) continue to function, they cannot be said to have integrity.

Human disturbances that mimic or simulate natural disturbances are less likely to threaten species than are disturbances radically different from the natural regime. Species have evolved along with disturbances. Natural selection has provided species with ways to escape, tolerate, or exploit natural disturbances, so that life histories of species are often closely tied to a specific disturbance regime. For example, longleaf pine (Pinus palustris) depends on frequent, low-intensity fires to prepare a seedbed of exposed mineral soil and to drive out competing hardwoods. If fires are suppressed for more than several years, hardwoods invade the site and eventually dominate. Any human-induced change in the type, size, frequency, intensity, or seasonality of disturbance can be expected to affect biodiversity. Logging, livestock grazing, and other management practices will be less disruptive when they simulate or mimic natural disturbances. Exactly how closely they must resemble the natural regime to avoid biotic impoverishment is a question unanswered for any ecosystem. 8131*907

Ecosystem management requires cooperation among agencies and landowners and coordination of inventory, research, monitoring, and management activities. Because political and landownership boundaries do not conform to ecological boundaries, agencies and landowners will need to cooperate in order to manage resources and conserve biodiversity effectively. Both within and among agencies, the usually separate functions of biological inventory, research, monitoring, and management should be united into one holistic scheme.

Management must be adaptive. Much land management in the past has been trial and error, with errors often not recognized until long after damage was done. Even then, destructive practices often continued because no rigorous studies linked degradation of habitats to specific management practices. Recognizing that every land management practice is an experiment with an uncertain outcome, research and monitoring should be coordinated to test hypotheses about the effects of management treatments on biodiversity and ecological integrity. n43 The information gained from these experiments should be used to adjust management in a desirable direction.

Natural areas have a critical role to play as benchmarks or control areas for management experiments. This value was recognized by Aldo Leopold, who pointed out that wilderness provides a "base-datum of normality" for a "science of land health." n44 Scientists shudder to think of experiments without controls, but this is the case for much land management today. Existing natural areas are imperfect baselines for many reasons, but they are the best we have. Ecosystem management, because it is essentially experimental and adaptive, requires natural areas as controls. Unfortunately, many of the proponents of ecosystem management today propose it as an alternative to protected areas, rather than as a necessary complement.

III. Translating Principles into Action

The emerging principles of conservation biology I have outlined here are not laws. The pathways of natural processes are not entirely predictable. The probabilistic character of all natural phenomena and all statements about nature is not congruent with a legal system that demands certainty. The apparent inability of many people - including 8131*908 lawyers, judges, legislators, and journalists - to appreciate the inherent uncertainty in science is a primary reason why many scientists feel uncomfortable in the courtroom, testifying at congressional hearings, or being involved in public debates of any kind. We might think wishfully that science is becoming more certain over time and that eventually our probabilistic statements about nature can be replaced by firm declarations of fact. How many board feet of timber can we cut each year in the Pacific Northwest without driving the northern spotted owl to extinction? How much coastal sage scrub must we protect, and in what size pieces, to save the California gnatcatcher? Precisely how much water and at what times of year must it be delivered to the Everglades in order to keep the ecosystem healthy? Scientists can provide estimates in response to each of these questions, but the estimates are vague and highly uncertain. Surely these estimates will narrow as we learn more - or will they? In ecology and conservation biology, the more we learn, the more we recognize our profound ignorance. Statements in ecology textbooks written twenty or thirty years ago are much more confident than those made today. Today we recognize that non-linear dynamics are the way of nature; therefore extrapolation from past trends or current conditions is hazardous. Ecosystems are always changing and the changes are often unpredictable. Does this mean that we have no standards by which to judge the efficacy of conservation measures or suitability of management practices? Not at all. Although the new paradigm in ecology emphasizes change and non-equilibrium conditions rather than balance or stability, it does not imply that all changes are desirable. As stated by Botkin:

To accept certain kinds of change is not to accept all kinds of change. Moreover, we must focus our attention on the rates at which changes occur, understanding that certain rates of change are natural, desirable, and acceptable, while others are not. As long as we refuse to admit that any change is natural, we cannot make this distinction and deal with its implications. n45

Conclusion

The principles of conservation biology proposed in this Article should be robust in a changing environment. In fact, most of these principles assume a changing and unpredictable environment. The challenge ahead is implementing these principles to specific conservation challenges, knowing that few of the people making the ultimate 8131*909 decisions have anything but a rudimentary understanding of nature. Those legal scholars, lawyers, and policy-makers who do appreciate these principles should be in the forefront of efforts to apply them to real-world conservation, while along the way educating their colleagues.

Legal Topics:

For related research and practice materials, see the following legal topics:
Environmental LawNatural Resources & Public LandsFish & Wildlife ProtectionInternational Trade LawTrade AgreementsEnvironmental ProvisionsEndangered SpeciesInternational Trade LawTrade AgreementsEnvironmental ProvisionsFish

FOOTNOTES:

n1. Daniel B. Botkin, Discordant Harmonies: A New Ecology for the Twenty-first Century 6-13 (1990); see Steward T.A. Pickett et al., The New Paradigm in Ecology: Implications for Conservation Biology Above the Species Level, in Conservation Biology: The Theory and Practice of Nature Conservation Preservation and Management 65, 70-74 (Peggy L. Fiedler & Subodh K. Jain eds., 1992).

n2. See Judy L. Meyer, The Dance of Nature: New Concepts in Ecology, *69 Chi.-Kent L. Rev. 875 (1994).*

n3. R. Edward Grumbine, What is Ecosystem Management?, 8 Conservation Biology 27, 29-32 (1994).

n4. Michael E. Soule & Bruce A. Wilcox, Conservation Biology: Its Scope and Its Challenges, in Conservation Biology: An Evolutionary-Ecological Perspective 1, 1 (Michael E. Soule & Bruce Wilcox eds., 1980); Michael E. Soule, What Is Conservation Biology?, 35 Bioscience 727, 727 (1985).

n5. Reed F. Noss, The Wildlands Project: Land Conservation Strategy, Wild Earth, Special Issue 1992, at 10, 11-15.

n6. Endangered Species Act, *16 U.S.C. 1531*-1544 (1988 & Supp. 1993); National Forest Management Act, *16 U.S.C. 1600*-1687 (1988 & Supp. 1993). The ESA states that various species threatened with extinction "are of esthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people." *16 U.S.C. 1533*(a)(3).

n7. See, e.g., *Sierra Club v. Froehlke, 816 F.2d 205 (5th Cir. 1987)*(party opposing construction must prove the inadequacy of the builder's environmental impact statement).

n8. *16 U.S.C. 1533*(b)(3)(A) ("After receiving the petition of an interested person ... to add a species to [the endangered or threatened species list], the Secretary shall make a finding as to whether the petition presents substantial scientific or commercial information indicating that the petitioned action may be warranted.").

n9. K.S. Shrader-Frechette & E.D. McCoy, Statistics, Costs and Rationality in Ecological Inference, 7 Trends in Ecology & Evolution 96, 97 (1992).

n10. See generally Randall M. Peterman, Statistical Power Analysis Can Improve Fisheries Research and Management, 47 Canadian J. Fisheries and Aquatic Sci. 2 (1990).

n11. Randall M. Peterman, The Importance of Reporting Statistical Power: The Forest Decline and Acidic Deposition Example, 71 Ecology 2024, 2027 (1990); Shrader-Frechette, supra note 9, at 97.

n12. Shrader-Frechette & McCoy, supra note 9, at 98.

n13. Id.

n14. Barbara L. Taylor & Tim Gerrodette, The Uses of Statistical Power in Conservation Biology: The Vaquita and Northern Spotted Owl, 7 Conservation Biology 489, 490 (1993).

n15. See generally Martin H. Belsky, Environmental Policy Law in the 1980's: Shifting Back the Burden of Proof, *12 Ecology L.Q. 1 (1984).*

n16. See generally Frank E. Egler, The Nature of Vegetation: Its Management and Mismanagement (1977).

n17. Stephen J. Gould, A Special Fondness for Beetles, 102 Nat. Hist. 4, 12 (1993).

n18. Jack W. Thomas et al., A Conservation Strategy for the Northern Spotted Owl 23 (1990); David Wilcove & Dennis Murphy, The Spotted Owl Controversy and Conservation Biology, 5 Conservation Biology 261, 261 (1991).

n19. Thomas et al., supra note 18, at 23.

n20. Michael E. Soule & Daniel Simberloff, What Do Genetics and Ecology Tell Us About the Design of Nature Reserves?, 35 Biological Conservation 19, 32 (1986).

n21. See *16 U.S.C. 1533.*

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U.S. Fish & Wildlife Service

Why Save Endangered Species?

Since life began on Earth, countless creatures have come and gone, rendered extinct by naturally changing physical and biological conditions.

Since extinction is part of the natural order, and if many other species remain, some people ask: "Why save endangered species? Why should we spend money and effort to conserve them? How do we benefit?"

Congress answered these questions in the preamble to the Endangered Species Act of 1973, recognizing that endangered and threatened species of wildlife and plants "are of esthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people." In this statement, Congress summarized convincing arguments made by scientists, conservationists, and others who are concerned by the disappearance of unique creatures. Congress further stated its intent that the Act should conserve the ecosystems upon which endangered and threatened species depend.

Although extinctions occur naturally, scientific evidence strongly indicates that the current rate of extinction is much higher than the natural or background rate of the past. The main force driving this higher rate of loss is habitat loss. Over-exploitation of wildlife for commercial purposes, the introduction of harmful exotic (nonnative) organisms, environmental pollution, and the spread of diseases also pose serious threats to our world's biological heritage.

Passenger pigeons once numbered in the billions but now exist only in museums.

Chip Clark/Smithsonian Institution

Conservation actions carried out in the United States under the Endangered Species Act have been successful in preventing extinction for 99 percent of the species that are listed as endangered or threatened. However, species loss on a global scale continues to increase due to the environmental effects of human activities.

Biologists estimate that since the Pilgrims landed at Plymouth Rock in 1620, more than 500 species, subspecies, and varieties of our Nation's plants and animals have become extinct. The situation in Earth's most biologically rich ecosystems is even worse. Tropical rainforests around the world, which may contain up to one half of all living species, are losing millions of acres every year. Uncounted species are lost as these habitats are destroyed. In short, there is nothing natural about today's rate of extinction.

Right: Former rainforest habitat

Below: Intact rainforest at dawn

CIA

CECB/BU Photo Library

Courtesy of Great Smoky Mountains National Park and the American Chestnut Foundation

Not too long ago, almost one quarter of the trees in the Appalachian forests were American chestnuts. They helped support not only wildlife but the people living among them. Chestnuts were an important cash crop for many families. As year-end holidays approached, nuts by the railroad car were sold and shipped to northeastern cities. Chestnut timber, strong and rot resistant, was prized for building barns, fences, furniture, and other products. This photograph of the Shelton family, taken around 1920, shows the size American chestnut trees once reached.

First detected in 1904, an Asian fungus to which native chestnuts had little resistance appeared in New York City trees. The blight spread quickly, and by 1950 the American chestnut was virtually extinct except for occasional root sprouts that also became infected. Organizations such as the American Chestnut Foundation are working with plant breeders to develop a disease resistant strain and restore it to the eastern forests.

Benefits of Natural Diversity

How many species of plants and animals are there? Although scientists have classified approximately 1.7 million organisms, they recognize that the overwhelming majority have not yet been catalogued. Between 10 and 50 million species may inhabit our planet.

None of these creatures exists in a vacuum. All living things are part of a complex, often delicately balanced network called the biosphere. The earth's biosphere, in turn, is composed of countless ecosystems, which include plants and animals and their physical environments. No one knows how the extinction of organisms will affect the other members of its ecosystem, but the removal of a single species can set off a chain reaction affecting many others. This is especially true for "keystone" species, whose loss can transform or undermine the ecological processes or fundamentally change the species composition of the wildlife community.

Chisos Mountain hedgehog

Tracy Brooks

Gray wolf

The gray wolf is one such keystone species. When wolves were restored to Yellowstone National Park, they started to control the park's large population of elk, which had been over consuming the willows, aspen, and other trees that grew along streams. The recovery of these trees is cooling stream flows, which benefits native trout, and increases nesting habitat for migratory birds. Beavers now have willow branches to eat, and beaver dams create marshland habitat for otters, mink, and ducks. Wolves even benefit the threatened grizzly bear, since grizzlies find it easier to take over a wolf kill than to bring down their own elk.

Contributions to Medicine

One of the many tangible benefits of biological diversity has been its contributions to the field of medicine. Each living thing contains a unique reservoir of genetic material that has evolved over eons. This material cannot be retrieved or duplicated if lost. So far, scientists have investigated only a small fraction of the world's species and have just begun to unravel their chemical secrets to find possible human health benefits to mankind.

No matter how small or obscure a species, it could one day be of direct importance to us all. It was "only" a fungus that gave us penicillin, and certain plants have yielded substances used in drugs to treat heart disease, cancer, and a variety of other illnesses. More than a quarter of all prescriptions written annually in the United States contain chemicals discovered in plants and animals. If these organisms had been destroyed before their unique chemistries were known, their secrets would have died with them.

A few hundred wild species have stocked our pharmacies with antibiotics, anti-cancer agents, pain killers, and blood thinners. The biochemistry of unexamined species is an unfathomed reservoir of new and potentially more effective substances. The reason is found in the principles of evolutionary biology. Caught in an endless "arms race" with other forms of life, these species have devised myriad ways to combat microbes and cancer-causing runaway cells. Plants and animals can make strange

The rosy periwinkle, a plant native to the island of Madagascar, has yielded powerful substances effective in treating childhood leukemia and other diseases.

M. Plotkin

The peeling bark of the Pacific yew, original source of the drug taxol.

Dave Powell/U.S. Forest Service

molecules that may never occur to a chemist. For example, the anti-cancer compound taxol, originally extracted from the bark of the Pacific yew tree, is "too fiendishly complex" a chemical structure for researchers to have invented on their own, said a scientist with the U.S. National Cancer Institute. Taxol has become the standard treatment for advanced cases of ovarian cancer, which strikes thousands of women every year. But until the discovery of taxol's effectiveness, the Pacific yew was considered a weed tree of no value and was routinely destroyed during logging operations.

Some of the most promising natural wonder drugs come from compounds not usually associated with healing: poisons. One pharmaceutical company is marketing a blood thinner based on the venom of the deadly saw-scaled viper. A protein from another Asian pit viper is being studied because it appears to inhibit the spread of melanoma cells, and a compound from the venom of some tarantula species may lead to new treatments for neurological disorders such as Parkinson's disease.

Tarantula

Jim Rorabaugh

Some farmers put up nest boxes to attract bats that consume harmful insects.

Merlin D. Tuttle/
Bat Conservation
International

Biodiversity and Agriculture

Many seemingly insignificant forms of life are beginning to show important benefits for agriculture. Farmers are using insects and other animals that prey on certain crop pests, as well as using plants containing natural-toxins that repel harmful insects. These are called "biological controls," and in many cases they are a safe, effective, and less expensive alternative to synthetic chemicals.

Thomas Jefferson once wrote that "the greatest service which can be rendered any country is to add a useful plant to its culture, especially a breadgrain." It has been estimated that there are almost 80,000 species

Texas wild rice

Sue Emery

of edible plants, of which fewer than 20 produce 90 percent of the world's food. If underutilized species are conserved, they could help to feed growing populations. One grain native to the Great Lakes States, Indian wild rice, is superior in protein to most domesticated rice, and its increasing commercial production earns millions of dollars annually. Crossing it with a related but endangered species, Texas wild rice, could result in a strain adaptable to other regions of the country.

Christopher Best

Walker's manioc is an endangered plant endemic to the Lower Rio Grande Valley of southern Texas and northeastern Mexico. It is closely related to an important crop plant, cassava, which is a staple food in many parts of the world. Walker's manioc could contain genes that provide salt, drought, cold, or disease resistance for strains of commercial cassava.

Ted Swem

Peregrine falcon

Environmental Monitors

Many individual species are uniquely important as indicators of environmental quality. The rapid decline in bald eagles and peregrine falcons in the mid-20th century was a dramatic warning of the dangers of DDT—a strong, once widely used pesticide that accumulates in body tissues. (It hampered fertility and egg-hatching success in these species.) In another example, lichens and certain plants like the eastern white pine are good indicators of excess ozone, sulfur dioxide, and other air pollutants. Species like these can alert us to the effects of some contaminants before more damage is done.

Freshwater mussels are also very effective environmental indicators. The eastern United States boasts the richest diversity of freshwater mussels in the world. These animals are filter feeders, drawing in water and straining out food particles. Their method of feeding helps to keep our waters clean. But because mussels

Richard Biggins

Fanshell mussel

filter material from the water, they are often the first animals to be affected by water pollution. They tend to accumulate whatever toxins, such as chemicals in agricultural and industrial runoff, are present in their habitat. Too much pollution can eliminate the mussels. Other threats to mussel populations include siltation, the introduction of competing nonnative mussels, stream channelization and dredging, and the impoundment of free-flowing streams and rivers. Today, most native freshwater mussel species are considered to be endangered, threatened, or of special concern.

Amber darter

J.R. Shute/Conservation Fisheries, Inc.

Ecosystem Services

As the pioneering naturalist Aldo Leopold once stated, "To keep every cog and wheel is the first precaution of intelligent tinkering." As we tinker with ecosystems through our effects on the environment, what unexpected changes could occur? One subject of increasing concern is the impacts these effects can have on "ecosystem services," which is a term for the fundamental life-support services provided by our environment. Ecosystem services include air and water purification, detoxification and decomposition of wastes, climate regulation, regeneration of soil fertility, and the production and maintenance of biological diversity. These are the key ingredients of our agricultural, pharmaceutical, and industrial enterprises. Such services are estimated to be worth trillions of dollars annually. Yet because most of these services are not traded in economic markets, they carry no price tags that could alert society to changes in their supply or declines in their functioning. We tend to pay attention only when they decline or fail.

John and Karen Hollingsworth

Wetlands, like those at the John Heinz National Wildlife Refuge near Philadelphia, clean water, control flooding, and provide quality wildlife habitat.


Keith Weller

Alpine pennycress

An emerging field called phytoremediation is an example of the ecosystem services provided by plants. Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment. Certain plant species known as metal hyperaccumulators have the ability to extract elements from the soil and concentrate them in the easily harvested plant stems, shoots, and leaves. The alpine pennycress, for example, doesn't just thrive on soils contaminated with zinc and cadmium; it cleans them up by removing the excess metals. In the home, houseplants under some conditions can effectively remove benzene, formaldehyde, and certain other pollutants from the air.


Laura Riley

Birdwatching at J.N. "Ding" Darling National Wildlife Refuge on Florida's Gulf Coast.

Other Economic Values

Some benefits of animals and plants can be quantified. For example, the Texas Parks and Wildlife Department calls birding "the nation's fastest growing outdoor recreation." It estimates that birders pump an estimated $400 million each year into the state's economy. A host of small rural towns host festivals to vie for the attention of these birders. Nationwide, the benefits are even more amazing. In a recent study (Birding in the United States: A Demographic and Economic Analysis), the U.S. Fish and Wildlife Service estimated that wildlife watching—not just bird watching—generated $85 billion in economic benefits to the nation in 2001.

Steve Hillebrand

Whooping cranes in Texas.

George Lavendowski

Attwater's greater prairie-chicken, another Texas bird.

Intangible Values

If imperiled plants and animals lack a known benefit to mankind, should we care if they disappear? If a species evolves over millennia or is created by divine intent, do we have a right to cause its extinction? Would our descendants forgive us for exterminating a unique form of life? Such questions are not exclusive to scientists or philosophers. Many people believe that every creature has an intrinsic value. The loss of plant and animal species, they say, is not only shortsighted but wrong, especially since an extinct species can never be replaced. Eliminating entire species has been compared to ripping pages out of books that have not yet been read. We are accustomed to a rich diversity in nature. This diversity has provided inspiration for countless writers and artists, and all others who treasure variety in the natural world.

Suzanne L. Collins/Center for North American Herpetology

San Francisco garter snake

Among its many values, wildlife is a source of inspiration. For example, the bird paintings by John James Audubon, such as this image of ivory-billed woodpeckers, are recognized as fine art. Once feared to be extinct, the ivory-bill was rediscovered recently in Arkansas.

In his story "The Bear," writer William Faulkner depicted a number of creatures that are now rare, including wolves, panthers, the ivory-billed woodpecker, and, of course, the animal now known as the Louisiana black bear.

USFWS

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Cover photo: *Geranium arboreum*, an endangered Hawaiian plant.